Electric Bomb Fuzing Instrumentation System Test Program on the F/A-18A Aircraft

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Abstract- Naval Air Systems Command, PMA-201, is currently conducting an Electric Fuzing Dud Investigation Systems Engineering Analysis of the F/A-18 Fighter Aircraft. To support that effort, the Naval Air Warfare Center Aircraft Division (NAWCAD) Air Vehicle/Stores Compatibility Division (Air 4.11.2) was tasked by PMA-201 to develop a quick install, deployable Electric Fuzing Instrumentation System (EFUZIS) to collect electrical fuzing data during practice bombing missions. The system consists of a commercial off-the-shelf (COTS) digital recorder and specially designed signal conditioner that will record real-time non-telemetered electric fuzing data during bomb drops. The purpose of the testing was to qualify the instrumentation system for use on testing and training squadron F/A-18C/D aircraft. Ground testing was done over a period of four days and consisted of 73 ground drops utilizing Mk-82 bomb bodies in the parent rack and canted vertical ejection rack (CVER) configurations. Electric fuzing data was collected during these drops and analyzed to ensure that proper signal timing, amplitude, polarity, and duration were being recorded. The results of the ground tests showed that the EFUZIS performed as designed. Flight testing followed to test the effects of the flight environment on the recorder system. Flight testing consisted of a single flight during which two Mk-82 bombs were released using the CVER configuration. In addition, dynamic test maneuvers were performed to evaluate the effects of load factors on the EFUZIS. Flight test results showed that the instrumentation system recorded all the required parameters and that the recorder was able to withstand the flight environment. Overall, the EFUZIS demonstrated excellent potential for gathering electrical fuzing data as proven by the extensive ground and flight testing performed by the test team.

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Figure 1 - F/A-18A Test Aircraft
(Test Configuration Not Shown)

1. INTRODUCTION

The U.S. Navy's weapon system integration team for the F/A-18A fighter/attack aircraft was tasked to evaluate the feasibility of installing a digital recorder in the aircraft's weapon pylon to record electric fuzing signals during electronically fuzed weapon releases. Ground testing had been conducted previously on the F/A-18A with analog recording systems, but such systems were not viable for obtaining data during flight. The compact digital recording system could be placed in the pylon for extended periods of time and record valuable data during actual weapon releases. To conduct a flight test, it first had to be proven by bench and ground testing that the recorder functioned without effecting normal armament system operation. Electronic modifications were designed into the recorder firmware for this application that allowed it to be easily integrated with the F-18 electric fuzing system. With the bench and ground tests showing that the recorder functioned as designed, testing continued to demonstrate operation in flight under bomb release conditions. The qualification effort is discussed from an overall perspective, as well as details of the bench, ground, and flight tests.

2. TEST AIRCRAFT AND EQUIPMENT

F/A-18A Aircraft

The F/A-18A Hornet is a single seat, dual-engine, supersonic fighter/attack aircraft built by McDonnell Aircraft Corporation (now Boeing). Distinguishing aircraft features include a variable camber mid-fuselage wing with fuselage mounted leading edge extensions and twin vertical stabilizers which are angled 20 degrees outboard and located well forward of the slab-type horizontal stabilators. The aircraft is configured with nine external weapon stations, five of which are capable of carrying and releasing air-to-ground ordnance, and utilizes an integrated Stores Management Set (SMS) computer with a MIL-STD-1553 data bus for armament system control. The test aircraft was equipped with a modified SUU-63 pylon in which the electric fuzing instrumentation system was installed. The system was placed in the AMAC compartment of the pylon. No pylon modifications were required for the installation. Cables were designed and built for this application and were installed into the pylon to interface the recorder with the electric fuzing system of the aircraft. In addition, a jumper cable was installed in the fuselage to connect the AWW-4 electric fuzing power supply to the Walleye video lines at the armament computer to carry the power supply voltage down to the recorder in the pylon. The video lines were disconnected from the armament computer to prevent voltage feedback into the computer. The test aircraft is shown in Figures 1 and 2.

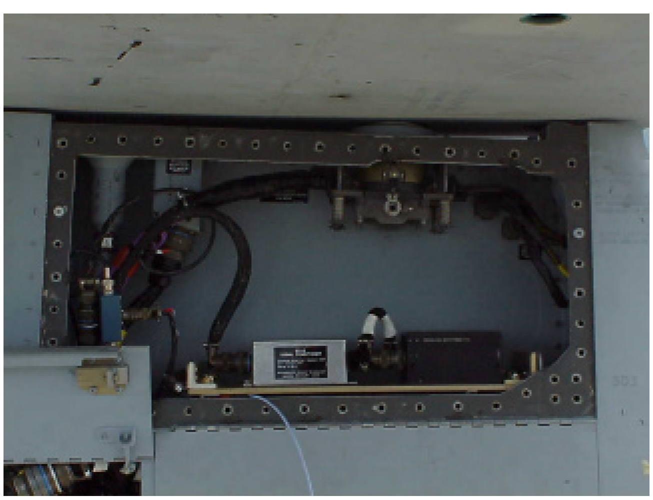

Figure 2. SUU-63 Pylon with Recorder and Signal Conditioner Installed in AMAC Compartment

F/A-18 Electric Fuzing System

Electrical fuzing is provided for JSOW, JDAM, Laser Guided Munitions and General Purpose Bombs with electrical fuzes installed. The armament computer provides the control for the Fuze Function Control Set (FFCS), AN/AWW-4. Electrical Fuzing operation is provided by the mission computer system control, armament computer control, FFCS, and weapon interface. The mission computer (MC) system provides the program select function for the Stores Management System (SMS). When electrical fuzing is selected as part of the program, the MC system provides this data to the armament computer to control the FFCS. The armament computer controls the discrete signals to the FFCS for the electrical fuze options. The MC system sends the armament computer the selected program. When electrical fuzing is selected as part of the program, the armament computer sends the discrete signals to the FFCS. Depending on bomb type, fuze type and delivery attitude, the low voltage select and negative polarity select will be enabled as a part of the selected program. Pickle relay enable is provided when Air-to-Ground ready exists. A-t-G ready exists when the priority station is selected, program complete exists and the MASTER switch on the master arm control panel assembly is set to ARM. Weapon release is enabled when the weapon release mode command from the MC system exists and the A-t-G weapon release switch on the aircraft controller grip assembly is pressed. AWW-4 On Enable provides 28vdc to the Power On Relay during BIT and when electrical fuzing is part of the selected program. The FFCS enables ±195 or ±300vdc to the weapons that require electrical fuzing.

FMU-139 Electronic Fuze

The FMU-139 Series consists of FMU-139/B, FMU-139A/B, FMU-139B/B, FMU-139(D-2)/B, and FMU-139(D-2)A/B; hereafter commonly referred to as the FMU-139 series fuze (Note: All FMU-139/B fuzes are being removed from service). The fuzes are Joint-Service (Navy/Air Force) fuzes with multiple settings, which must be preset during weapon assembly and can be delivered in either high-drag (retarded) or low-drag (unretarded) mode. The major physical differences from other Navy electrical fuzes are: (1) the gag rod and arming wire housing are located in the center of the faceplate, and (2) the fuze is secured in the tail fuze well of the bomb by a separate closure ring, which is screwed into the fuze well. The faceplate contains a low-drag arm time rotary switch, a high-drag arm/delay rotary switch and a 2.0 second/instantaneous interlock button. The FMU-139 series incorporates three arming times (2.6, 5.5, and 10.0 seconds) and has three functioning delays available (10, 25, 60 milliseconds and instantaneous). The arming times are in-flight selectable and the functioning delay (high-drag arm/delay switch) must be set during weapon assembly. The FMU-139 arming wire housing, which protrudes from the center of the fuze faceplate, contains the gag rod and gag rod sleeve. This arming-wire housing, together with the gag rod's red-and-black striped sleeve, which will extend from the housing to indicate an armed/unsafe condition, is roughly equivalent in function to the pop-out indicator of other electrical fuzes. Once the sleeve is extended and the red-and-black striping is visible, the fuze gag rod/sleeve cannot be reset (pushed back) to render the fuze safe. The gag rod and gag rod sleeves are secured in the arming-wire housing by a safing pin. On the FMU-139A/B, the gag rod is shorter than on the FMU-139/B and the arming wire is pushed into a slot, rather than threaded as for the FMU-139/B.

Mk-122 Safety Switch

The Mk-122 arming safety switch (Figure 3) connects the fuze control circuits in the aircraft to the electric fuze circuits in the bomb. This switch provides an open circuit and a radiation hazard shield to prevent electromagnetic radiation from entering the fuze circuits. While the weapon is loaded, the coaxial cable of the switch is plugged into the receptacle of the aircraft's electrical arming unit. When the bomb is suspended from the bomb rack, the lanyard is attached to a fixture on the rack or pylon. Upon bomb release, the lanyard pulls the lanyard pin and closes the fuze circuit. The lanyard is long enough so the weapon separates from the bomb rack suspension hooks before the lanyard pin is pulled from the switch. This is a safety feature that ensures the fuze does not receive a charging voltage in the event of a weapon release failure. The coaxial cable is longer than the lanyard, which permits sufficient time for the charging voltage to pass from the electrical arming unit on the aircraft to the fuze electric circuits on the bomb before weapon separation.

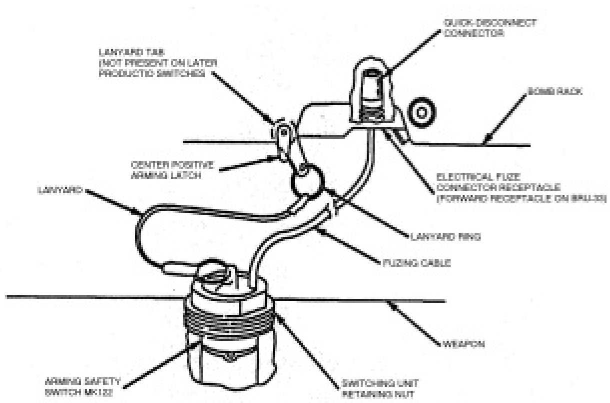

Figure 3. Mk-122 Safety Switch

F-18 Ground Test Bed

The F-18 Ground Test Bed, depicted in Figure 4, is an F/A-18C, Lot 11, aircraft that was deemed non-flightworthy after a landing mishap. It was acquired by the Air Vehicle/Stores Compatibility Division to be used as a weapons systems ground test asset. It has functional weapons system avionics and cockpit displays. Of the nine weapon stations, stations 2, 3, 4, 7, and 8 are operational.

Figure 4. F-18 Ground Test Bed

Electric Fuzing Instrumentation System

Electric Fuzing Instrumentation System (EFUZIS) consists of the EDR-3 data recorder (Figure 5) and a signal conditioner. The EDR-3 is a six-channel, solid state, digital recorder, and is supplied by Instrumented Sensor Technology Company. The six channels can receive analog or digital inputs within a range of –2 to +2 volts. The recorder is capable of sampling up to 3200 Hz per channel, and has a maximum event length of 9,999 samples, at a maximum of 5,000 events. Its primary power source is aircraft power, with a lithium battery back up. The unit measures 4.4 x 4.2 x 2.2 inches and weighs 2.2 lbs. The signal conditioner was designed and developed by IST to be used in conjunction with the EDR3 recorder. The signal conditioner will step down the high voltage electric fuzing signals to a level within the voltage range that the EDR3 requires. It will also be powered by the aircraft system and have a lithium battery backup.

The signal conditioner and recorder were mounted in the AMAC compartment of the SUU-63 pylon. No pylon modifications were required for the installation. Cables were designed and built for this application and were installed into the pylon to interface the recorder with the electric fuzing system. In addition, a jumper cable was installed in the fuselage to connect the AWW-4 electric fuzing power supply to the Walleye video lines at the armament computer to carry the power supply voltage down to the recorder in the pylon. The video lines were disconnected from the armament computer to prevent voltage feedback into the computer.

The EFUZIS was designed to record the following parameters of the F-18 electric fuzing system:

- AWW-4 Power Supply Output
- BRU-32 Bomb Rack Fuzing Input

- BRU-32 Bomb Rack Fuzing Output
- Fuze Current
- Fire Pulse

The EFUZIS is triggered by the fire pulse, and then records the fire pulse and the other parameters. The recorded data is stored in digital memory until downloaded to a laptop computer, where it is processed and analyzed by EFUZIS-specific software. The data may then be exported to a text document for viewing by other software.

Figure 5. EDR-3 Digital Data Recorder.

3. Bench Tests

The intent of the bench tests was to demonstrate that the instrumentation system could record the fuzing parameters into memory and download the data in accordance with design specifications. At this time, signals were not scrutinized for proper timing, pulse width, and amplitude. The concern was mainly for general functionality of the EFUZIS. The test setup consisted of an AWW-4 fuzing power supply, BRU-32 bomb rack simulation circuit, FMU-139 fuze simulator, an interface unit for selecting fuzing voltage polarities and amplitudes, the IST recorder and signal conditioner, and a laptop computer with the Microsoft Windows operating system.

Test Method

The laptop was used to set up and program the data recorder. This was accomplished using unique software that was provided with the recorder from Instrumented Sensor Technology Company. After the recorder was set up, several runs were executed using the interface unit to select the four possible electric fuzing voltages: ±195V and ±300V. The BRU-32 simulation circuit effectively approximated the signal timing that a bomb rack would have given, but, as mentioned before, the signal timing was not of great concern during the bench tests. The EFUZIS was successful in acquiring the fuzing voltage and current signals, storing them to memory, and downloading the data to the laptop. After sufficient repetition, it became apparent that the risk to moving on to aircraft ground releases was very low.

4. Ground Tests

The ground tests were conducted outside the 4.11.2 Ordnance Electric Facility at Patuxent River, MD. The tests consisted of 73 ejections of Mk-82 inert bomb bodies from the instrumented pylon on the F-18 Test Bed, which was configured with SUU-63 Pylons and BRU-32 Bomb Racks. The EFUZIS was installed in the station two pylon, and a 2,000 LB inert bomb was loaded on each inboard station for ballast. For part of the tests, a BRU-33A/A Canted Vertical Ejection Rack (CVER) was used, and was loaded on the instrumented pylon. Power was supplied to the aircraft systems by the Ordnance Electric Facility. FMU-139 Fuze Simulators were used in place of actual FMU-139 fuzes. However, they were not installed in the bomb tail fuze wells. The simulators were external to the bombs and connected by test cables, and provided a load profile signature identical to the FMU-139.

For the ground tests, a modification to the parameter list was made. Instead of recording the fuzing output from the bomb rack, the electric fuzing voltage at the input to the fuze simulator was recorded. Although this configuration cannot be used in flight, it afforded the ability to ensure that the Mk-122 safety switch was functioning correctly.

Test Method

The ground releases included a combination of configurations using the parent rack as well as the CVER. The F-18 Test Bed was parked on the ramp next to the Ordnance Electric Lab. Foam blocks were placed on the ramp to cushion the fall of the bombs, and wheel guards were put in place to prevent the bombs from impacting the landing gear. Once the aircraft was loaded and positioned, release and control checks were performed according to standard procedures.

Ordnance Electric (O&E) personnel occupied the Hulk cockpit to prepare the aircraft for each bomb ejection. Radio communication was used among the test team to signal readiness. The EFUZIS was prepared for data capture before each test event, even though recorder's memory capacity was large enough to record all the data points. This was done to ensure that no modifications to the test setup were necessary in between the tests. When all equipment and personnel were ready, the cockpit occupant signaled that the aircraft was prepared for weapon release.

After each test event, the bomb(s) was retrieved and reloaded onto the aircraft. The project engineer and supporting personnel reviewed the data and prepared the equipment for the next event. The data for each release was analyzed on-site for comparison to expected results.

Ground Test Data

A sample of the ground test data is presented in figure 6. To make the chart more legible, the less relevant data has been excluded, leaving the AWW-4 electric fuzing power supply output voltage, the fire pulse (trigger), and the fuze current. For the event depicted, the electric fuzing options selected were:

- Low Drag Arm Time Fuze Setting = X
- High Drag Arm/Delay Fuze Setting = 2.6/INST
- Electric Fuzing DDI Settings:
  - Arm Time = Instantaneous
  - Mode = Free Fall

These options provided for an output of +300V from the fuzing power supply, as can be seen from the figure. When release consent is given, the fuzing power supply turns on, applying 300V, followed by the fire pulse, which triggers the recorder. The operation of the recorder is such that when the trigger signal is sensed, the recorder records a small window of data before the trigger and a larger window afterwards, both of which are programmable. This ensures that all of the relevant data is acquired.

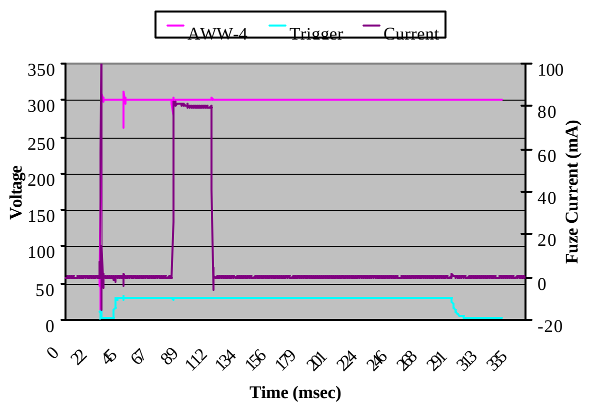

Figure 6. Ground Test Data.

When the bomb rack opens, the weapon is released, and the safety lanyard is pulled from the Mk-122 switch in the bomb, allowing fuzing voltage to be passed to the fuze simulator. When the voltage reaches the fuze simulator, it begins charging. As shown on the right axis of the graph, the fuze charging current reaches 80 milliamps, and remains there for approximately 29 milliseconds, at which point the Mk-122 cable is pulled from the bomb rack fuzing receptacle. These values are within the fuze specification [1]. Also noted in figure 6 is a spike in the current waveform that coincides with the turning on of the AWW-4. This is caused by reactance due to the series resistor that monitors the fuze current signal. It is inherent to the system and has no impact on the operation of the fuzing system.

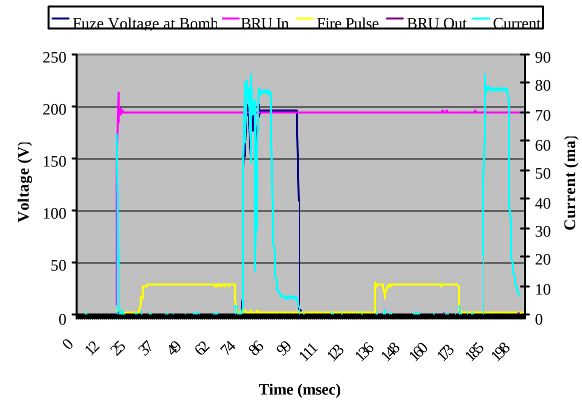

Figure 7. CVER Configuration.

Figure 7 shows the results from a ground release in which the BRU-33A/A CVER was used. The options chosen for this drop was:

- Low Drag Arm Time Fuze Setting = X
- High Drag Arm/Delay Fuze Setting = 2.6/INST
- Electric Fuzing DDI Settings:
  - Arm Time = Delay
  - Mode = Free Fall
  - Release Interval = 100 ms

The data shows two fire pulses, 104 ms apart, and two fuze charging current pulses. Also shown in the figure is the fuze voltage received by the first fuze simulator, coinciding with the first current pulse. Since the delay arming time option was chosen for this event, the output from the fuzing power supply is +195V, as expected. It should be noted that the current profile is different with the application of 195V as opposed to 300V. As can be seen in figure 6, with 300V applied, the fuze current reaches 80 milliamps, and remains there for as long as the fuze voltage is applied. In the case of 195V, however, the current rises to 80 milliamps, remains there for approximately 11-13 ms, then falls to 6 milliamps, and remains there for the duration of fuze voltage application. This is typical fuze operation for the FMU-139. Also shown in figure 7 is a considerable amount of noise during the release of the first bomb from the CVER. Similar noise was seen in several of the ground test drops, and analysis confirmed that the current signal still had sufficient power for the fuze to operate normally.

Ground Test Results

A total of 73 ground drops were performed on the F-18 Test Bed. During execution of the tests, there were four events in which the fuze simulator failed to charge. One of the events is shown in figure 8.

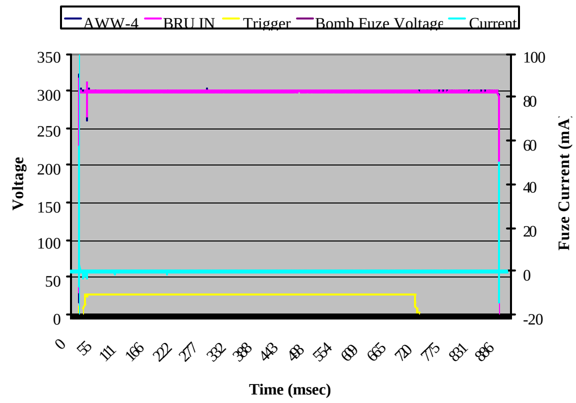

Figure 8. Fuze Simulator Failed to Charge.

The fire pulse was initiated, triggering the recorder. AWW-4 fuzing power supply voltage was turned on, but did not reach the fuze simulator, as indicated by the absence of the fuze voltage at the input to the simulator ("Bomb Fuze Voltage" on the graph). The typical current spike occurs, coinciding with power supply activation, indicating that current was available. Since power supply voltage was turned on, and the bomb rack operated correctly, it follows that the Mk-122 safety switch failed to operate, and was responsible for precluding the fuze simulator from receiving a charging current. Analysis of the other three failures proved that, in each case, the Mk-122 switch failed to operate.

The ground test phase demonstrated that the Electric Fuzing Instrumentation System performed according to design specification, and was suitable to be flight tested.

5. Flight Test

After completion of ground tests, one flight for a total of 1.2 hours was flown in the local NAWC-AD, Patuxent River, areas. The aircraft was loaded with two MK-82s on a CVER on station two. The MK-82s were configured with conical fins, FMU-139 tail fuzes, and steel nose plugs. The Stores Management System was set for a manual mode release, 60 ms release interval, quantity two, and multiple one. The fuze was set to an instantaneous functioning time and a ten second arming time. The MK-82s were dropped in 1G level flight at 5000 Ft AGL. In addition to the drops, aircraft maneuvers were conducted to evaluate the airworthiness of the system[2]. The maneuvers performed were steady heading sideslip, 45° negative dive, negative 1G pushover, negative 2G pushover, 360° roll, wind up turn (4.5G and 6.5G), wind down turn (4.5G), and field touch and go's. After completion of the test flight, data was downloaded to a laptop computer for analysis.

Flight Test Data

Data from the flight test is shown in figure 9. The parameters recorded during the flight test were AWW-4 power supply output, BRU-32 bomb rack input, fire pulse, and fuze current. The BRU-32 output signal cannot be recorded in the CVER configuration, because the connector to which the recorder would normally be connected is used by the CVER.

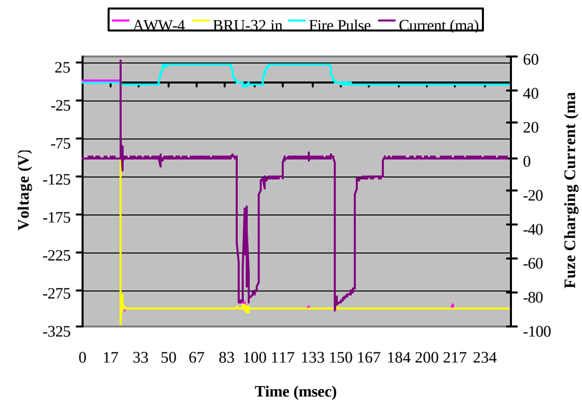

Figure 9. Flight Test Data.

The data is very similar to that from ground tests and is typical for the CVER configuration. The spike in the current waveform occurs when the AWW-4 turns on, just as in the ground tests, and noise can be seen in the first current pulse. The current waveform shape is standard for the 195V fuze voltage, with the exception of the steady state current level. As noted in the ground test data of figure 7, the current reaches a peak level of ±80 milliamps, then falls to ±6 milliamps, approximately. During the flight test however, the steady state current value was approximately -11 milliamps. This is higher than seen in the ground tests, and is currently under investigation.

Flight Test Results Summary

The flight test showed that the EFUZIS performed as designed and could be used for the gathering of electrical fuzing data. The aircraft maneuvers that were performed further proved that the EFUZIS hardware could withstand the flight environment.

6. Conclusions

The Electric Fuzing Instrumentation System demonstrated excellent potential for gathering electrical fuzing data in support of the F-18 Electric Fuzing Dud Investigation Systems Engineering Analysis currently being undertaken by Naval Air Systems Command PMA-201. The test team proved with extensive ground and flight testing that the EFUZIS functioned properly and could withstand the harsh environment of aircraft flight.

7. References

[1] Military Specification, MIL-F-85815A, Fuze, Bomb, Electronic, FMU-139A/B, 9 September 1993.

[2] U.S. Naval Test Pilot School Flight Test Manual, USNTPS-FTM-No. 103, Fixed Wing Stability and Control, Theory and Flight Test Techniques, January 1997.

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